

California. Division of
Mines and Geology
Bulletin
no.72(1916)



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State Mineralogist

[San Francisco]

BULLETIN No. 72

[November, 1916]

The Geologic Formations of California

WITH

Reconnaissance Geologic Map



CALIFORNIA STATE PRINTING OFFICE
SACRAMENTO
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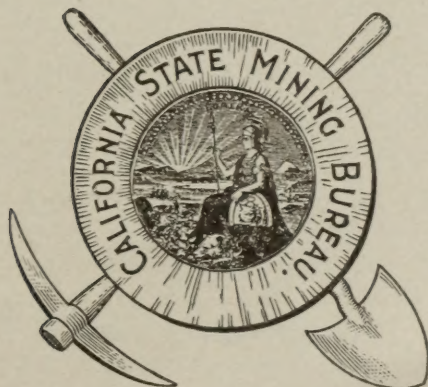
The Geologic Formations of California

WITH

Reconnaissance Geologic Map

COMPLIMENTS OF
F. MCN. HAMILTON
STATE MINERALOGIST

By JAMES PERRIN SMITH



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STATE PRINTING OFFICE
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The Geologic Formations of California

JAMES PERRIN SMITH.

INTRODUCTION.

A quarter of a century has passed since the preparation of the Preliminary Geological Map of California, published by the California State Mining Bureau in 1891.

The State Mineralogist, Mr. Fletcher Hamilton, was resolved to signalize the end of the second quarter of a century of studies in the geology of California by taking stock, and showing what we have done in that period. The writer agreed, at his request, to sum up all the available information in map form. This Bulletin, with the Reconnaissance Geologic Map of California that accompanies it, is essentially a report of progress for this period. He is well aware that there are many imperfections. Certain areas have not been mapped at all, and others only in a general way. Also there is much information buried in unpublished notes and maps of private individuals and corporations that would materially improve the map, if it were available. Such unpublished material as could be obtained has been used, along with the much greater mass of published information in maps and descriptive papers in the publications of the United States Geological Survey, California State Mining Bureau, California Academy of Sciences, Bulletins of the Department of Geology of the University of California, and the various scientific publications of America and foreign countries.

This last quarter of a century has been made notable for California by the mapping of the Gold Belt by the U. S. Geological Survey, by H. W. Turner, Waldemar Lindgren, J. S. Diller and F. L. Ransome; by areal mapping in the Coast Ranges by A. C. Lawson, J. C. Branner, H. W. Fairbanks and R. Arnold; by the detailed mapping of the oil fields by R. Arnold, H. R. Johnson, F. M. Anderson, and R. Anderson; by the stratigraphic work in the Klamath Mountains of J. S. Diller and O. H. Hershey; by the studies in the continental formations by J. C. Merriam in the desert regions, and by W. Lindgren in the Tertiary river deposits.

C. D. Walcott has added the Cambrian to our geologic column, in the desert region of southeastern California. J. S. Diller has added the Silurian and Devonian, and greatly extended our knowledge of the Carboniferous. The Carboniferous and Triassic stratigraphy and paleontology have been studied in detail by J. P. Smith. The Jurassic stratigraphy has been described by A. Hyatt and J. P. Smith, and the paleobotany of that system by L. F. Ward and W. M. Fontaine.

The Cretaceous stratigraphy has been described by C. A. White, J. S. Diller, T. W. Stanton, and F. M. Anderson, and the paleobotany of the Cretaceous by L. F. Ward.

The Tertiary formations have been the most lucrative field in the past twenty-five years. The invertebrate faunas of this system have been studied with great care by W. H. Dall, T. W. Stanton, F. M. Anderson, R. Arnold, R. E. Dickerson, C. E. Weaver, B. L. Clark, J. P. Smith and others. The vertebrates have been described by J. C. Merriam, and the paleobotany by F. H. Knowlton.

The most striking addition to our knowledge of the geologic history of California has been made in the studies of the Quaternary invertebrates by R. Arnold, and of the vertebrates by J. C. Merriam.

Physical geology has received valuable contributions of worldwide interest from the work of J. S. Diller on mountain structure in relation to physiography; of A. C. Lawson on the types of structure of the Coast Ranges in their relation to seismology; of J. S. Diller and R. S. Holway on vulcanism as exhibited by Lassen Peak, the only active volcano in the United States; of I. C. Russell, A. C. Lawson, and R. S. Holway on glaciation; of W. Lindgren and H. W. Turner in mountain structure and physical history in their relations to the ore deposits of the Gold Belt.

The petrography of the State has been worked over thoroughly. The rocks of the Sierra Nevada have been studied by H. W. Turner, W. Lindgren and F. L. Ransome; those of the Klamath Mountains by J. S. Diller and O. H. Hershey; those of the Coast Ranges by A. C. Lawson, Charles Palache, H. W. Fairbanks and J. P. Smith; those of the Sierra Madre by R. Arnold, A. M. Strong and O. H. Hershey.

The physiography of California has become classic from the work of J. S. Diller in the Klamath region; of W. Lindgren, H. W. Turner and I. C. Russell in the Sierra Nevada; of A. C. Lawson in the Coast Ranges; of F. L. Ransome in the Great Valley; and of H. W. Fairbanks, A. C. Lawson, and R. S. Holway on the general features of the State.

Economic geology has not been neglected, notable contributions having been made by W. Lindgren on the auriferous gravels, and on the gold-quartz of the Sierra Nevada; by T. C. Hopkins on structural materials; by G. F. Kunz on gems; by R. Arnold and R. P. McLaughlin on the petroleum industry; by various members of the State Mining Bureau on the quicksilver and the copper industry.

The mineralogy of the State has been adequately treated by A. S. Eakle, A. F. Rogers, G. D. Louderback, F. L. Ransome and G. F. Kunz, and many new minerals added to the world's list.

In the past twenty-five years California has furnished at least her share of geologic literature of interest beyond the boundaries of the State. She has had in that period the services of a large and efficient

force of trained workers, whose papers are cited below. But even this quarter of a century of investigations by a small army of workers has not been sufficient for the preparation of a complete geologic map. The area of the State, being 155,908 square miles, is too great for that to be possible, extensive stretches having been little studied. Consequently our knowledge of the State is very uneven, and much remains to be done, especially in the Klamath Mountains and northern Coast Ranges, and in the Mojave and Colorado deserts.

DETAILED LEGEND FOR RECONNAISSANCE GEOLOGIC MAP OF CALIFORNIA.

Compiled by J. P. SMITH.

- 1 Q **QUATERNARY.**
Including alluvium, lake beds, marine San Pedro formation on the coast, and desert wash.
- 2 Tp **PLIOCENE.**
Including marine Merced, Purisima, Fernando, San Diego and Etchegoin formations of the coast and San Joaquin Valley; the Santa Clara, Tulare and Paso Robles fresh-water beds, and some delta formations.
- 3 Tm **MIOCENE.**
Including marine Vaqueros, Monterey, Santa Margarita, San Pablo and Jacalitos formations of the Coast Ranges and San Joaquin Valley; also some lake-beds in the Sierra Nevada, and in the desert region; also the Tuscan tuffs of the head of the Sacramento Valley.
- 4 Te **EOCENE.**
Including marine Tejon and Martinez formations of the Coast Ranges and San Joaquin Valley; the Ione formation of the western flank of the Sierra Nevada; also some lake-beds.
- 5 **AURIFEROUS GRAVELS.**
Ancient river channels of the Sierra Nevada and Klamath Mountain.
- 6 T **TERTIARY UNDIFFERENTIATED.**
Including some marine beds in San Diego County, in Marin and Sonoma counties; also some lake-beds and desert accumulations.
- 7 Kc **UPPER CRETACEOUS.**
Chico and Horsetown formations of the Coast Ranges and Sacramento Valley.
- 8 Kk **LOWER CRETACEOUS.**
Knoxville formation of the Coast Ranges and Klamath Mountains.
- 9 K **CRETACEOUS UNDIFFERENTIATED.**
Including the Cretaceous of the western side of the Sacramento Valley, and of the middle Coast Ranges, embracing both Chico and Knoxville.

10 **J JURASSIC.**

Including the Mariposa formation of the Gold Belt, and associated metamorphic and igneous rocks; also the Hardgrave, Milton, Potem, Modin, and Monte d'Oro formations of the same region.

11 **Jf FRANCISCAN.**

Cherts, slates, serpentines, metamorphic pre-Cretaceous rocks of the Coast Ranges.

12 **Tr TRIASSIC.**

Including marine limestones and shales, Pit, Hosselkus, Cedar and Sailor Cañon formations of the Gold Belt, and the Meekoceras beds of Inyo County.

13 **C CARBONIFEROUS.**

Including the Bragdon, Baird, McCloud and Nosoni formations of the Klamath Mountains, the Calaveras formation of the Gold Belt, and associated metamorphic and igneous rocks.

14 **D DEVONIAN.**

Including Kennett limestones and shales of the Klamath Mountains and associated igneous rocks; also similar beds in Plumas and Inyo counties.

15 **S SILURIAN-ORDOVICIAN.**

Including the Montgomery limestone of the Sierra Nevada, also the Eureka and Pogonip formations of southeastern California.

16 **C CAMBRIAN.**

Limestones and shales of Inyo County and the Mojave and Colorado deserts.

17 **Pm PALEOZOIC METAMORPHICS UNDIFFERENTIATED.**

Including limestones, slates and associated igneous and metamorphic rocks of the Klamath Mountains and the Mojave Desert.

18 **Sl SANTA LUCIA.**

Gneisses, schists and crystalline limestones of the Coast Ranges.

19 **Am PRE-CAMBRIAN METAMORPHICS.**

Including gneisses, schists, quartzites and crystalline limestones of the Klamath Mountains and the Mojave and Colorado deserts.

20 | V | VOLCANICS.

Lavas, andesites, basalts and rhyolites, chiefly Tertiary in age.

21 | P | PLUTONICS.

Including the batholiths, granite, gabbro, and quartz diorites, of the Sierra Nevada, Klamath Mountains, Coast Ranges, Sierra Madre, and southeastern California.

22 | Oil | OIL FIELDS.

Small areas in solid black; large areas, cross-hatched.

THE GEOLOGIC RECORD OF CALIFORNIA.

The geologic record of California is exceedingly complete for a single geographic region, because of the two ancient and persistent seas that covered some portion of its surface during each geologic period. These seas were the Pacific Ocean and the Great Basin Sea.

Great Basin Sea. The older portion of the geologic record, from the Cambrian to the top of the Middle Jurassic, has been preserved chiefly in the sediments of the Great Basin Sea, while during those ages that part of California which was afterward covered by the Pacific Ocean was either above water, or has had its sediments so much metamorphosed that their age is not positively determinable.

The Great Basin Sea of Paleozoic and early Mesozoic time covered approximately the area of the Great Basin of the present age, sometimes more, and sometimes less, dwindling away gradually from the noble expanse of the Carboniferous sea to the shrunken remnant in early Mesozoic time. This basin at all times was directly connected with the Pacific Ocean, by a broad passage to the northwest; and during a part of the Paleozoic, especially during the period of the Coal Measures, it was joined to the Mississippian Sea. At all other times it was exclusively western, and the marine Triassic and Jurassic history of the United States is its peculiar property. It has played very much the same part in the geologic history of North America as the ancient Mediterranean, or Tethys, did in the history of Europe, though on a much smaller scale, since it was epicontinental, and not intercontinental. The Cambrian, Silurian, and Devonian sediments of California are mere fragments of little area, representing only a small part of the entire time of those ages. The Carboniferous, however, is fairly complete, all three major divisions being fully represented by marine faunas. The Triassic period is well represented; the Lower Triassic is nearly as good as the standard American section of Idaho; the Middle Triassic has both of the greater divisions, although the main portion is not nearly so complete as the standard section of the West Humboldt Range in Nevada. The Upper Triassic of California is the standard

for this epoch in America, and compares very favorably with the rest of the world in the richness of its faunas, and the completeness of the record. The Jurassic section of the Great Basin Sea is the most complete in the United States, having portions of each stage from Lias to Kelloway, inclusive; but it is fragmentary, the faunas being poorly preserved and scanty. It is not comparable with the Jurassic record of Alaska and British Columbia, and nowhere approaching that of South America. With this epoch the marine column of the Great Basin ends abruptly, as the sea was obliterated at the beginning of the Cordilleran revolution.

The Tertiary record of the Great Basin region is preserved in the ancient lake beds and other continental accumulations, which continued to form through the Pleistocene.

Pacific Record. The marine record of California from the bottom of the Upper Jurassic through the Quaternary was kept exclusively by the Pacific Ocean. This was divided between two provinces, or areas of sedimentation, the Sierra Nevada, and the Coast Ranges, but the distribution was not balanced. The Pacific province is one of the great geosynclines, with sediments approximating seventy thousand feet in thickness, and undergoing subsidence more or less continuously, though spasmodically, from the Triassic onward, interrupted by great periods of orogenic activity. This is a part of that grand structural feature of the continent of which the Great Valley, the Gulf of California, the Willamette Valley, and Puget Sound, are mere remnants.

The recognizable Paleozoic and early Mesozoic sediments are confined to the Sierra Nevada and Klamath Mountains, while the Cretaceous and Tertiary strata are most complete in the Coast Ranges. The Sierran record is fragmentary, the formations being incomplete, separated by great unconformities, including great masses of tuffs and igneous rocks and showing evidence of important recurring orogenic and volcanic activity.

The Coast Range province, too, showed this same phenomenon in its Paleozoic and early Mesozoic sediments, but from the bottom of the Cretaceous to the middle of the Miocene conditions were more uniform, indicating moderately quiet advance and retreat of the sea, with minor unconformities, smaller masses of igneous intrusives, and outpourings of surface lavas. The Coast Range revolution, about the middle of the Miocene epoch, broke the monotony of this history, and for a time there was much mountain-making activity. Minor outpourings of lava occurred along the coast, while farther to the northeast the Columbian lava flood overwhelmed an area of more than two hundred thousand square miles, and the rejuvenation of the Sierra Nevada was beginning.

The Cretaceous section of the Coast Ranges is more complete than that of any other single province in America. It lacks only the uppermost portion, and shows a variety of conditions not seen anywhere else, from the boreal faunas of the Knoxville to the tropical faunas of the Horsetown and Chico epochs, with fossil floras interbedded in every formation.

The Tertiary marine section of the Coast Ranges is not only the most complete in America, but also more complete than that of any other single geographic region in the world. Every minor division is fully represented by marine faunas, and most of them have fresh-water beds intercalated, with fossil plants and freshwater animals.

The Quaternary marine section of the Coast Ranges is the most complete that has been described, for this is almost the only known region where there has been much post-Quaternary orogenic activity. In nearly all other regions the Quaternary sediments are still buried under the oceans in which they were deposited. Great stretches of the State, the Great Valley, and the intermountain valleys, are covered with alluvium, and portions of the high Sierras and Klamath Mountains are covered with morainal material. Also extensive areas of the Mojave plateau are concealed by desert wash, making the continental record of the Pleistocene very complete.

ROCK-FORMING AGENCIES OF CALIFORNIA.

Igneous Rocks. A large part of the surface of the State, a little less than one-half, is made up of crystalline rocks. Of these the most important group consists of deep-seated granitic rocks, granites, granodiorites, diorites, and gabbros, compounds of feldspars and ferro-magnesian minerals, such as hornblendes, pyroxenes, and mica. The greatest of these batholiths is the great igneous mass of the Sierra Nevada, making up the bulk of that mountain chain. Smaller batholiths of similar character are in the Sierra Madre, the White Mountain Range, the Klamath Mountains, and in the Santa Lucia Mountains.

Associated with the deep-seated granitic rocks in nearly all these regions there are numerous dyke-rocks, similar in chemical nature to the parent masses, but showing only a small surface area. In the Colorado and Mojave deserts, in the Santa Lucia Range, and in the Klamath Mountains there are large areas of gneisses and schists that are in part altered granitic rocks, but are not mapped as granites because of the uncertainty of their origin.

A second group is composed of basic intrusives, chiefly peridotites, now largely changed to serpentine, rich in olivine and other ferro-magnesian minerals. These cover great stretches in the Coast Ranges, where they are largely of Franciscan age, older than the Cretaceous; they also form less extensive masses in the Sierra Nevada. There are

also broad areas of serpentines in the Klamath Mountains, supposed to be Paleozoic in age. Associated with them are great bands of basic schists which may be altered igneous rocks.

A third group is composed of lavas, mostly andesites and basalts, surface flows from volcanoes. These are chiefly of Miocene Tertiary age; and, together with the less important rhyolite flows, they cover broad areas in northeastern California, and smaller patches in all the other mountain regions of the State. The flows in northeastern California are a part of the Columbian field, and doubtless came from fissure-eruptions. The others came from ordinary volcanoes, though in most cases the volcanic cones are long since destroyed. Mt. Shasta and Lassen Peak are the two grandest volcanoes of the State, the southern extension of the Cascade Range, still preserving their ancient form; and Lassen Peak has recently resumed its old-time activity.

Inorganic Sediments. The greater part of the surface of California, a little more than half, is made up of sediments. These are of two groups, (1) inorganic, and (2) organic.

The inorganic sediments are far greater in thickness and areal extent, sandstones and shales, derived from the decay of crystalline rocks. The quartz and undecomposed feldspars furnished the sand grains, and the decomposed feldspars furnished the clay for the shales. The sandstones of California are remarkable for the large quantity they contain of undecomposed fragments of minerals derived from the igneous rocks, so that they are more often arkose and greywacke than true sandstones.

Thick beds of aluminous shales, now largely changed to slates, are found in the Carboniferous and Jurassic rocks of the Sierra Nevada, and to a less extent in the Franciscan formation of the Coast Ranges. The Auriferous Slates also form the surface rocks of considerable areas in the Klamath Mountains.

Less altered shales are extensively developed in all the later formations of the State, from the Lower Cretaceous upward, although not on such a grand scale as in the older periods.

The greatest individual mass of sediments in California is formed by the Quaternary and Pliocene fluviatile deposits of the Great Valley. This mass is about four hundred miles long by fifty in width, and is several thousand feet thick in the middle, thinning out toward the edges, surpassing the enormous mass of Tertiary sediments. These valley deposits have been bored to a depth of three thousand feet, without reaching bedrock, but there are too few deep borings for an estimate of the average thickness to be possible.

A second great mass of clastic sediments is seen in the Tertiary sandstones of the Coast Ranges, which extend nearly the entire length of the State, and have a total thickness of about fifteen thousand feet,

although not all of this at any one place. A remnant of this series is seen along the western flank of the Sierra Nevada in the marine and brackish-water lone formation, and the upland equivalent is seen in the Auriferous Gravels.

A third great mass of sandstones is found in the Cretaceous of the Coast Ranges, where a thickness of about thirty thousand feet was deposited. This thickness surpasses by far that of the Tertiary sandstones, but the areal extent is much less. These, too, overlapped on the foot of the Sierra Nevada.

Smaller masses of sandstone, now largely changed to quartzite, are seen in the early Mesozoic and Paleozoic formations of the Sierra Nevada and Coast Ranges, but nowhere forming extensive surface areas.

On the western flank of the Sierra Nevada, throughout the Gold Belt, there are, in the late Paleozoic and in the Jurassic, thick beds of tuffs, or volcanic ash, now altered to greenstone schists. These in places have a thickness of several thousand feet, but do not form considerable areas of the surface rocks. These rocks are recognizable as tuffs by the fact that they are bedded, are fragmental, and contain fossils in some places.

Organic Sediments. These do not make much of a figure on the areal map of the State, but play a large part in its economic history. They are limestones, siliceous shales, and plant accumulations in the form of coal or lignite.

The limestones are entirely of organic origin, with the exception of some smaller occurrences of late spring deposits, or calcareous tufa, which, however, are large enough to be used in the manufacture of cement. The great masses of limestone are confined to the Paleozoic and early Mesozoic, though as late as the middle of the Jurassic period there are some large beds of limestone. They are formed of ground-up shells, corals, and foraminifers, that lived in quiet, clear waters, but are now largely crystalline, most of the evidence of their organic origin having been destroyed in the great mountain-making revolutions that have passed over them. The formation of limestone on a large scale in California was confined to epochs that we know from other evidence were warm, and also to epochs when sheltered, clear seas covered portions of the State. In such seas corals and foraminifers abounded, and the evidence of their rock-forming activity is still visible in the coral reefs of the Paleozoic and Triassic, and the Fusulina limestone of the Carboniferous.

From the middle of the Mesozoic up to the Eocene it was still warm enough at times for reef-building corals and foraminifers to have flourished in the seas of California; but the warm epoch of the Middle Jurassic was a time of igneous activity, and during the Cretaceous

there was too much sand and mud poured into the water for these organisms to find a favorable habitat.

Limestones, at least in part formed by corals, have a thickness of several thousand feet in the Cambrian of Inyo County, but the areal extent is unknown. The Devonian of Shasta and Siskiyou counties shows coral reef rock to the thickness of several hundred feet, of small area. These are all surpassed in the great masses of Carboniferous limestone, of the White Mountains, the western flank of the Sierra Nevada, and the Klamath Mountains, where the lenticular beds sometimes attain a thickness of two thousand feet. There are also extensive and thick masses of limestone in the Klamath Mountains of Siskiyou County, which are supposed to be Paleozoic, but are not known to contain any fossil evidence of their age.

The Santa Lucia limestone, in the Coast Ranges, of doubtful Paleozoic age, also occurs in large beds, amounting to several hundred feet in thickness, now changed to marble.

The Upper Triassic of Shasta and Plumas counties has lenses of limestone in places four or five hundred feet thick, forming important topographic features, and largely formed by the agency of corals.

The Franciscan series of the Coast Ranges has similar limestone masses of lenticular form, amounting in places to a few hundred feet in thickness, and wholly destitute of fossils, except a few traces of foraminifers.

The Cretaceous lacks limestone beds, except a local accumulation of shell limestone in the Knoxville formation of Colusa County, where a thickness of only a few feet is developed.

The Eocene of the Santa Cruz Mountains has some thin beds of limestone, and the Miocene of Santa Barbara, San Luis Obispo, and Orange counties has shell limestone amounting to as much as fifty feet in thickness. With the exception of these local occurrences there are no limestone masses in the marine beds of California from the middle of the Jurassic to the Quaternary, the Jurassic and Knoxville being characterized by thick beds of shale, and the other formations, from the Horsetown up, by enormous beds of sandstone.

Siliceous Organic Sediments. Among the most remarkable features of the stratigraphy of California are the thick beds of siliceous organic sediments. In the Monterey shale of the Middle Tertiary in the Coast Ranges such sediments are extensively developed, and in places reach a thickness of five thousand feet. These are not shales in the ordinary sense, for they are chiefly organic in origin, the remains of the microscopic diatoms and radiolaria. Similar deposits are known also in the Eocene of the middle Coast Ranges, but on a smaller scale. These organic siliceous shales are of great economic importance, for they have furnished nearly all of the petroleum of California.

Similar masses of siliceous organic sediments are known in the Coast Ranges in the Franciscan formation, of the earlier Mesozoic; they are no longer shales, but hard, flinty rocks, with the organic matter long since removed, and the fossil tests of radiolaria almost entirely destroyed, so that the rocks now show little resemblance to organic sediments.

In the Mother Lode region of the Sierra Nevada there are somewhat similar chert masses, in beds supposed to be Jurassic in age. These too are probably of radiolarian origin. In the Middle Triassic of Shasta County a series of siliceous shales almost without sand grains, several hundred feet thick, likewise was probably formed partly from the shells of siliceous organisms.

The Lower Carboniferous and the Devonian of Shasta and Siskiyou counties also contain many hundreds of feet of fine-grained so-called siliceous shales that are probably, at least in part, metamorphosed organic sediments. Shells of diatoms and radiolaria are extremely rare in all these older beds, but organic silicia is very soluble, and even a slight degree of metamorphism destroys the delicate tests, and thus obliterates the evidence of their origin.

Coal Deposits. During the Eocene epoch plant remains accumulated to a considerable extent in the swamps of the old embayment of California, especially along the western flank of the Sierra Nevada near Ione, in the Siskiyou embayment, the Coast Range island area of the Mt. Diablo region, and in the middle Coast Ranges of San Benito and Fresno counties. These leaf beds have since been compacted into lignite, and in a few places into true coal.

Chemical Deposits. In Kern, San Bernardino, San Diego and Inyo counties there are extensive chemical precipitates of salt, soda, borax, and gypsum, concentrates from the old lakes and salt pans of the arid region, from Tertiary up to the present. The areal extent is not large, but they are scattered over enormous stretches of country, and are of great present or prospective economic importance.

Mesozoic						Cenozoic									
Jurassic			Cretaceous			Tertiary							Quaternary	System	
Middle	Upper		Lower		Upper	Eocene	Oligo- cene	Miocene		Pliocene		Pleistocene			
Dolite	Kim- meridge	Portland	Neocomian	Gault	Cenomanian Turonian	Midway	Clatsopne		Lower	Upper					
	Auriferous Slates		Shasta		Chico										
	Mariposa		Knoxville	Horseshoe		Martinez	Tejon	Astorian	Vaqueros	Monterey	Santa Margarita San Pablo	San Diego	Santa Barbara	San Pedro	
	Mariposa slates of the Gold Belt with <i>Aucella erinngtoni</i> and <i>Cordioeris alternans</i> .		Upper Knoxvill shales of Coast Ranges with <i>Aucella crassicolis</i> .		Horseshoe shales of Sacramento Valley with <i>Desmoceras hoffmanni</i> , <i>Phylloceras oregonense</i> , <i>Lytoceras batesi</i> .	Lower Chico sandstones with <i>Schlotheimia oregonensis</i> .									
	Tufts and shales of the Gold Belt with <i>Peristhynonotus colfaxi</i> .		Lower Knoxvill shales with <i>Phylloceras knoxvillense</i> and <i>Aucella plicata</i> .		Upper Chico beds with <i>Platycrinurus</i> , <i>Phylloceras ramosum</i> , and <i>Turritella chocoensis</i> .	Sandstones of Martinez with <i>Photodonta musuta</i> and <i>Turritella pacificocensis</i> .									
	Hinchman tuff and sandstone of Plumas County, with reef corals.		Sandstones of Ft. Tejon, Martinez, and Merced Falls with <i>Veneridiscus planicosta</i> and <i>Turritella rostrata</i> .		Sandstones of San Lorenzo Cruz County.	Sandstones of Monterey and San Luis Obispo counties, with <i>Turritella mazoni</i> , <i>Megastoma matthewsoni</i> and <i>Pecten magnifica</i> .									
	Briones formation of Alameda County with <i>Scutella grevilliana</i> . Mariposa and Fresno sandstones with <i>Pecten discalis</i> , <i>P. rockhami</i> , <i>Turritella ocyana</i> and <i>Ficus kernianus</i> .		Sandstones of San Diego and Half Moon Bay, with <i>Pecten hedleyi</i> and <i>Scutella interlineata</i> .		Merced Purissima	Sandstones of Salinas Valley, San Pablo Bay and the Coalinga region, with <i>Pecten rubicundus</i> , <i>P. estrellanus</i> , <i>Ostrea titan</i> and <i>Tamiosoma gregaria</i> .									
	Deadman Island beds.		Los Cerritos beds.			Terrace formations									LAND EQUIVALENT.
	Paso Robles		Glacial beds.			Santa Clara and Tulare lake beds.									
	Upper flora of Mount Diablo region. Mohawk lake beds of Sierra Nevada.		Ione formation			Coal beds of Mt. Diablos region with subtropical flora.									
	Oroville flora		Oregon flora			Flora of southern Oregon supposed to be Jurassic, but possibly associated with marine Knoxvill forms.									
	Monte de Oro states of Oroville, with lower Jurasic flora, associated with Knoxvill forms.		Shasta flora associated with Horseshoe and Knoxvill species.												

TABLE II. GEOLOGIC RECORD OF THE GREAT BASIN SEA IN CALIFORNIA.

Cenozoic	Quaternary	Tertiary		
Mesozoic	Jurassic	Middle	Cordilleran revolution, uplift and metamorphism of Sierra Nevada and obliteration of the Great Basin Sea.	
			Hinchman tuff and sandstone of Plumas County, with Kelloway fauna, and reef-building corals.	
			Mormon sandstone and Thompson limestone of Plumas County with lower Oölite fauna.	
		Lower	Hardgrave sandstone of Plumas County, with Upper Liassic fauna.	
			Arietites limestones of Inyo County, California, and West Humboldt Range, Nevada.	
	Triassic	Upper	<i>Pseudomonotis</i> shales of Shasta and Plumas counties.	
			Hossekus limestone of Shasta County, with coral reefs. <i>Tropites sub-bullatus</i> fauna.	
		Middle	Pit shales of Shasta. Star Peak limestone of West Humboldt Range, Nevada.	
			Black limestone of Inyo Range, with Middle Triassic fauna	
		Lower	Gray limestone of Inyo Range, with Meekoceras fauna.	
Paleozoic	Carboniferous	Upper	Nosoni tuffs and shales of Shasta County, with fauna transitional to Permian.	
		Middle	McCloud limestone of Shasta County, with Coal Measures fauna, and coral reefs.	
		Lower	Baird shales of Shasta with Asiatic Subcarboniferous fauna.	
			Bragdon shales of Trinity County, without definite fauna.	
	Devonian	Middle	Kennett limestones of Shasta County, with coral reefs, <i>Favosites</i> , <i>Diphyphyllum</i> , etc.	
	Shurlan	Niagara	Montgomery limestone of Plumas County, with reef-building corals.	
	Ordovician	Pogo-nip & Eureka	Quartzites of Inyo County.	
	Cambrian	Lower	Olenellus limestone of Inyo County, with reefs of <i>Archaeocyathus</i> .	
Pre-Cambrian			Pre-Cambrian schists of Inyo County, and Mojave Desert.	

		COAST RANGES.			SIERRA NEVADA.		
Cenozoic	Tertiary	Quaternary					Terrace gravels.
							Glacial beds.
		Pliocene		Santa Clara and Tulare lake beds.			
		Miocene		Lake beds of Tesla, with Upper Miocene leaves.			Mohawk lake beds. Post-volcanic gravels, with Upper Miocene leaves.
							Chief volcanic period.
							Ocoya Creek sandstones, with marine fossils
		Oligocene					
Eocene		Lake beds of Corral Hollow, with Eocene plants.			Coal beds of Ione. Marine sandstones of Merced Falls.		
					Wanting.		
Mesozoic	Cretaceous	Chico		Chico flora	Plant beds in northern California, associated with Chico marine species.	Chico sandstones of Butte County, with marine fossils.	
		Horsetown		Shasta flora	Plant beds of northern California and southern Oregon associated with Knoxville and Horsetown marine species.	Erosion period. Record wanting.	
		Knoxville		Oregon flora	Plant beds of northern California and southern Oregon, supposed to be of Jurassic age.		
	Jurassic					Cordilleran revolution.	
		Franciscan					Cordilleran revolution.
							Colfax shales and altered tuffs, and igneous rocks. Marine record almost destroyed.
							Mariposa shales, with marine fossils of Upper Jurassic age.
Triassic					Sailor Cañon shales. Genesee Valley limestone and shales.		
					Limestones and quartzites of the Sierra Nevada, with Carboniferous fossils.		
					Taylorville formation of Plumas County.		
					Montgomery limestone of Plumas County with Niagara fauna.		
Paleozoic	Paleozoic	Santa Lucia					
Pre-Cambrian							

TABLE IV. GEOGRAPHIC RELATIONS OF WESTERN AMERICAN FOSSIL FAUNAS.

		MEDITERRANEAN REGION.	ORIENTAL REGION.	BOREAL REGION.	WEST AMERICAN REGION.
Recent			Marine fauna of Japan.		Marine fauna of California.
Quaternary					Warm water marine fauna of California.
			Cold water marine fauna of Japan.		Cold water marine fauna of California.
Tertiary	Neogene	Cold water marine fauna.	Cold water marine fauna of Japan.		Cold water marine fauna of California.
	Eocene	<i>Venericardia planicosta</i> Zone.			<i>Venericardia planicosta</i> Zone.
Cretaceous	Upper	<i>Schloenbachia</i> fauna of Europe.	<i>Schloenbachia</i> fauna of Japan, South India and East Africa.	Queen Charlotte Islands.	<i>Schloenbachia</i> fauna of California.
	Lower			<i>Aucella</i> fauna of North Europe, North Asia and Alaska.	<i>Aucella</i> fauna of the Knoxville Strata in California.
Jura	Upper			<i>Cardioceras</i> fauna with <i>Aucella</i> in Russia.	<i>Cardioceras</i> fauna with <i>Aucella</i> in California.
	Middle		Mediterranean type in India.	<i>Cadoceras</i> fauna of Alaska and the Boreal region.	Mediterranean type in California.
	Lower	<i>Arietites</i> fauna.	<i>Arietites</i> fauna in the Indian Ocean.	<i>Arietites</i> fauna of Alaska.	<i>Arietites</i> fauna in California and Nevada.
			<i>Pseudomonotis ochotica</i> fauna in Japan.	<i>Pseudomonotis ochotica</i> fauna, Alaska and North Siberia.	<i>Pseudomonotis ochotica</i> fauna in California and Nevada.
Trias	Upper	<i>Tropites subbullatus</i> fauna.	<i>Tropites subbullatus</i> fauna in India.	<i>Dawsonites</i> fauna of the Arctic Ocean.	<i>Tropites subbullatus</i> fauna in California.
	Middle	<i>Ceratites trinodosus</i> fauna.	<i>Ceratites trinodosus</i> fauna.	<i>Ceratites</i> fauna of Spitzbergen.	<i>Ceratites trinodosus</i> fauna in Nevada.
		<i>Beyrichites</i> fauna, Gulf of Ismid.			<i>Parapopanoceras</i> fauna in California.
		<i>Columbites</i> fauna, Albania.		<i>Olenkites</i> fauna of North Siberia.	<i>Columbites</i> fauna in Idaho.
Carboniferous	Lower	<i>Tirolites cassianus</i> fauna.	<i>Hedenstroemia</i> fauna of India.		<i>Tirolites</i> fauna in Idaho.
			<i>Meekoceras</i> fauna of India.	<i>Meekoceras</i> fauna of Spitzbergen.	<i>Meekoceras</i> fauna in California and Idaho.
		Atlantic type.	Asiatic type in India, Japan and China.	Asiatic type in Alaska and Siberia.	Asiatic type in California.



TABLE V. NEOCENE SECTIONS OF CALIFORNIA

Geological System	Period	Faunal Zone		San Diego		Los Angeles		Ventura		Santa Barbara		Key	
		Upper	Lower	San Diego	San Diego	Fernando formation	Fernando formation	Fernando formation	Fernando formation	Fernando formation	Fernando formation	Fernando formation	Fernando formation
Miocene	Upper	Zone of <i>Pecten bellus</i> .		Pacific Beach beds.		Upper Fernando Deadman Island beds with <i>Pecten caurinus</i> .				Upper Fernando with <i>Pecten bellus</i> .			
		Zone of <i>Pecten healeyi</i> and <i>Scutella interlineata</i> .		Sandstones with <i>Pecten healeyi</i> and <i>Ficus nodiferus</i> .		Middle Fernando with <i>Pecten hemphilli</i> .							
						Lower Fernando with <i>Pecten healeyi</i> and <i>Ficus nodiferus</i> .		Lower Fernando with <i>Pecten healeyi</i> .		Fugler's Point beds with Merced fauna.			
	Lower	Zone of <i>Pecten estrellanus</i> and <i>Trophon carisaensis</i> .		Sandstones with <i>Pecten carrizensis</i> and <i>P. cerrosensis</i> .									
		Zone of <i>Tamiosoma</i> and <i>Ostrea titan</i> .											
		Zone of <i>Pecten discus</i> .								<i>Pecten discus</i> beds.			
Pliocene	Lower	Zone of <i>Agasoma</i> and <i>Pecten andersoni</i> .				Diatomaceous shales resembling the Monterey		Sandstones with fauna like that of the Ocoya formation		Flinty shales resembling the Monterey.		Diatomaceous shales resembling the Monterey.	
		Zone of <i>Pecten magnolia</i> and <i>Turritella inezana</i> .				Sandstones with <i>Turritella inezana</i> .		Sandstones with <i>Turritella inezana</i> and <i>Mytilus mathewsoni</i> .		Sandstones with <i>Turritella inezana</i> and <i>Pecten magnolia</i> .		Sandstones with <i>Turritella inezana</i> and <i>Pecten magnolia</i> .	

V. NEOCENE SECTIONS OF CALIFORNIA.

[illegible]

TABLE VI. SYNOPSIS OF QUATERNARY HISTORY OF CALIFORNIA.

Recent	Subsidence epoch of Golden Gate and other bays	Invasion of Golden Gate River System by tide water and formation of the harbors of the West Coast. This subsidence has been going on until very recent time, for Indian shell mounds around the Bay of San Francisco are partly flooded.				
	Terrace epoch	Terrace	Period of uplift and scouring out the channels filled during the San Pedro epoch, forming terraces in the fluvialite sediments of San Benito Valley, and nearly all of the valleys of the Coast Range. The youngest (lowest) terraces of the San Pedro truncate the upper San Pedro beds and are later than they. The older (higher) wave-cut terraces of the West Coast probably date back to the Sierran epoch.			
Quaternary	Upper San Pedro	Champlain	Epoch of depression along the coast.	Warm water marine fauna.	Epoch of filling pre-existing valleys with gravels and other fluvialite sediments. Seen in the Salinas Valley, Santa Clara Valley, San Benito Valley, and the Great Valley.	
	Lower San Pedro		Coast stood 300-700 feet lower than now.	Cold water marine fauna.		
	Sierran epoch. Probably longer than all the rest of the Quaternary	Glacial	Period of elevation of the West Coast, forming the great cañons of the Sierras and the submerged cañons of the coast. A period of no marine sediment (now exposed). In part contemporaneous with the Glacial epoch, for the glaciers of the Sierra Nevada came down some of the cañons.			
Pliocene	Merced beds	Pre-Glacial	The West Coast then stood about 3,000 feet higher than now, as shown by the submerged Monterey Bay Cañon at a depth of 3000 feet.			
			The principal terracing along the coast took place at this time, and also the Channel Islands were connected with the mainland, as shown by the Santa Rosa Mammoth.			
			Period of depression and filling of troughs with marine Pliocene sediments, and formation of great Pliocene lakes above sea level.			

SOURCES OF DATA FOR THE GEOLOGIC MAP.

The geologic formations of California are much more numerous than those shown on the map. Some of the formations that have been named are of doubtful value; some are differentiated only locally; others are merely synonyms of formations better known by other names.

No subdivision is attempted of the pre-Cambrian metamorphics, although these probably include several formations. The Ordovician and Silurian are joined, for want of data for separation. The Carboniferous is not subdivided, although the section is very complete, and the Bragdon, Baird, McCloud, Nosoni and Wildwood formations are units of real value. But throughout the Gold Belt, the greatest area of Carboniferous rocks in the State, data for subdivision of the Calaveras formation are wanting.

The Triassic zones are capable of discrimination by paleontology, but they are too small to be mapped on a twelve-mile scale.

In the Jurassic, the folios of the U. S. Geological Survey distinguish not only a large number of sedimentary formations, but also numerous metamorphic and igneous rocks. These subdivisions become too confusing when reduced to the twelve-mile scale, which is true also of the subdivisions of the Franciscan formation in the Coast Ranges.

For the Cretaceous only two subordinate units are practicable, and for a portion of the State even this segregation can not be carried out.

Under the Tertiary, the Martinez and Tejon are merged in the Eocene; the Auriferous Gravels are given separately, although they are, at least in part, Eocene. Some lake beds and other continental deposits are put down under Tertiary undifferentiated.

The Vaqueros, Monterey, Santa Margarita, San Pablo and Jacalitos formations are merged under the Miocene, including also the San Lorenzo Oligocene beds, not separable on this scale.

The Merced, Purisima, San Diego, Fernando, and Etchegoin marine formations are merged under Pliocene, with which are united also the Tulare, Santa Clara and Paso Robles fresh-water beds.

The Quaternary includes alluvium, delta material, lake beds, glacial deposits, where differentiated, and a narrow fringe of marine beds along the coast.

The following are the chief sources of data for the geologic map of California, given by regions. It should be understood that reports covering the entire State, such as the Geological Survey of California by J. D. Whitney; the Pacific Railroad Reports by W. P. Blake, Thomas Antisell, J. S. Newberry, and T. A. Conrad; the Stratigraphy of North America by Bailey Willis, Professional Paper No. 71, U. S. Geological Survey, are not cited under the various subdivisions, although

of course they were used. It would be needless repetition to place these citations under the various headings.

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Northern End of the Range. J. S. Diller, *Geology of the Lassen Peak District*, 8th Annual Report, U. S. Geological Survey, Part I, pp. 395-432; *Lassen Peak Folio*, U. S. Geological Survey; *The Geology of the Taylorville Region*, Bull. 353, U. S. Geological Survey.

Gold Belt. The folios of the U. S. Geological Survey: W. Lindgren, *Colfax, Truckee, Sacramento, Placerville, Pyramid Peak*; W. Lindgren and H. W. Turner, *Smartsville, Marysville*; H. W. Turner, *Bidwell Bar, Downieville, Jackson*; H. W. Turner and F. L. Ransome, *Big Trees, Sonora*; F. L. Ransome, *Mother Lode*; H. W. Fairbanks, *Geology of the Mother Lode Region*, Report X of the State Mineralogist, pp. 23-90; H. W. Turner, *The rocks of the Sierra Nevada*, 14th Annual Report, U. S. Geological Survey, Part II, pp. 441-495. Further contributions to the geology of the Sierra Nevada, 17th Annual Report, U. S. Geological Survey, Part I, pp. 521-762. Waldemar Lindgren, *The gold quartz veins of the Nevada City and Grass Valley districts, California*, 17th Annual Report, U. S. Geological Survey, Part 2, pp. 1-262. *The Auriferous Gravels of the Sierra Nevada*, P.P. 73, U. S. Geological Survey. J. S. Diller, *Tertiary revolution in the topography of the Pacific Coast*, 14th Annual Report, U. S. Geological Survey, part 2, pp. 403-433.

Southern End of Sierra Nevada. A. C. Lawson, *the Geomorphogeny of the upper Kern basin*, Bull. Dept. Geol., University of California, Vol. 3, No. 15, pp. 291-376. A. Knopf and P. Thelen, *Sketch of the geology of Mineral King*, Bull. Dept. Geol., University of California, Vol. 4, No. 12, pp. 227-262. H. R. Johnson, *The geology and water resources of Antelope Valley*, Water Supply Paper No. 278, U. S. Geological Survey.

East of the Sierra Nevada. W. T. Lee, *Geology and water resources Owens Valley*, Water Supply and Irrigation Paper No. 181, U. S. Geological Survey. I. C. Russell, *The Quaternary history of Mono Valley, California*, 8th Annual Report, U. S. Geological Survey, Part I, pp. 269-394. A. Knopf, *Mineral resources of the Inyo and White mountains, California*, Bull. 540, U. S. Geological Survey, pp. 81-120. S. H. Ball, *A geological reconnaissance in southwestern Nevada and eastern California*, Bull. 308, U. S. Geological Survey. Various minor papers by H. W. Fairbanks, C. D. Walcott, G. K. Gilbert; Personal communications by H. W. Turner, A. M. Strong. Unpublished Geological Map of Inyo County by C. A. Waring, California State Mining Bureau, 1917.

MOJAVE DESERT.

J. E. Spurr, *Geology of Nevada south of the Fortieth Parallel and adjacent parts of California*, Bull. 208, U. S. Geological Survey. H. R. Johnson, *Geology and water resources of Antelope Valley*, Water Supply Paper No. 278, U. S. Geological Survey. C. L. Baker, *Notes on the later Cenozoic history of the Mojave Desert region in south-eastern California*, Bull. Dept. Geology, University of California, Vol. 6, No. 15, pp. 333-383, C. L. Baker, *Physiography and structure of the western El Paso range and the southern Sierra Nevada*, Bull. Dept. Geology, University of California, Vol. 7, No. 6, pp. 117-142. G. E. Bailey, *The saline deposits of California*, Bull. No. 24, California State Mining Bureau. W. P. Blake, *A geological reconnaissance of California*, Vol. 5, Reports, Pacific R. R. Survey. Bailey Willis, *The stratigraphy of North America*, P.P. 71, U. S. Geological Survey. M. R. Campbell, *Reconnaissance of the borax deposits of Death Valley and Mojave Desert*, Bull. 200, U. S. Geological Survey. O. H. Hershey, *The Quaternary of southern California*, Bull. Dept. Geology, University of California, Vol. 3, No. 1, pp. 1-30. S. H. Ball, *A geological reconnaissance in southwestern Nevada and eastern California*, Bull. 308, U. S. Geological Survey. G. A. Waring, *Springs of California*, Water Supply Paper No. 338, U. S. Geological Survey (Map of California). *Guidebook of the Western United States, Part C*, U. S. Geol. Survey, Bulletin 613.

COLORADO DESERT.

Various publications of the California State Mining Bureau, especially W. A. Goodyear, *San Diego County*, 10th Annual Report, State Mineralogist; and E. B. Preston, *Salton Lake*, Report XI, State Mineralogist. W. P. Blake, *Geological reconnaissance of California*, Vol. 5, Pacific R. R. Reports. H. W. Fairbanks, *Geology of San Diego County*, 11th Annual Report, State Mineralogist, pp. 76-120; Stephen Bowers, *Reconnaissance of the Colorado Desert Mining District*, Bulletin —, 1901; D. T. MacDougal, *Sketch of the geology and soils of the Cahuila Basin, The Salton Sea*, Publications of the Carnegie Institution, No. 193.

The Sierra Madre (Sierra de Los Angeles). The range extending from Point Conception in Santa Barbara County through San Diego and Imperial counties to Lower California, has generally been termed the Sierra Madre; F. L. Ransome has recently proposed to name this system the Sierra de Los Angeles. The new name will hardly displace the time-honored term.

H. W. Fairbanks, *Geology of San Diego County, etc.*, Report XI, State Mineralogist, pp. 76-120. G. H. Eldridge and R. Arnold, *Geology of the Santa Clara Valley, Puente Hills and Los Angeles Oil districts, California*, Bull. 309, U. S. Geological Survey. A. C. Lawson,

the post-Pliocene diastrophism of the coast of southern California. Bull. Dept. Geology, University of California, Vol. 1, No. 4, pp. 115-160. O. H. Hershey, The Quaternary of southern California, Bull. Dept. Geology, University of California, Vol. 3, No. 1, pp. 1-30. O. H. Hershey, Some crystalline rocks of southern California, American Geologist, Vol. 27, pp. 225-245. R. Arnold and A. M. Strong, Some crystalline rocks of the San Gabriel Mountains, Bull. Geol. Society of America, Nov. 16, pp. 183-204. R. Arnold, Geology and Oil resources of the Summerland district, California, Bull. 321, U. S. Geological Survey. R. Arnold and R. Anderson, Geology and oil resources of the Santa Maria district, California, Bull. 327, U. S. Geological Survey. R. Arnold, The palaeontology and stratigraphy of the marine Pliocene and Pleistocene of San Pedro, California, Mem. California Academy of Sciences, Vol. 3, pp. 1-420. R. E. Dickerson, The Martinez Eocene and associated formations at Rock Creek on the western border of the Mojave Desert area, Bull. Dept. Geology, University of California, Vol. 8, No. 14, pp. 289-298. H. W. Fairbanks, Geology of northern Ventura, Santa Barbara, San Luis Obispo, Monterey and San Benito counties, 12th Annual Report, State Mineralogist, pp. 493-526. R. P. McLaughlin and C. A. Waring, Petroleum industry of California, Bull. 69, California State Mining Bureau. Various minor county reports in the publications of the State Mining Bureau; Unpublished work of R. Arnold, J. R. Pemberton, and C. A. Waring.

THE ISLANDS OF THE SANTA BARBARA CHANNEL.

L. G. Yates, Stray Notes on the geology of the Channel Islands, Report IX, State Mineralogist, pp. 171-174. W. S. T. Smith, A geological sketch of San Clemente Island, 18th Annual Report, U. S. Geological Survey, Part 3, pp. 74-96. W. S. T. Smith, A topographic study of the islands of southern California, Bull. Dept. Geology, University of California, Vol. 2, No. 7, pp. 179-230. W. S. T. Smith, The geology of Santa Catalina Island, Proceedings California Academy of Sciences, 3d Ser., Geology, Vol. 1, No. 1, pp. 1-71.

COAST RANGES.

The Middle Coast Ranges, Point Concepcion to San Francisco. R. Arnold and R. Anderson, The geology and oil resources of the Santa Maria district, California, Bull. 327, U. S. Geological Survey. R. Arnold and R. Anderson, The geology and oil resources of the Coalinga district, California, Bull. 398, U. S. Geological Survey. R. Arnold and Harry R. Johnson, Preliminary report on the McKittrick-Sunset oil region, Kern and San Luis Obispo counties, California, Bull. 406, U. S. Geological Survey. H. W. Fairbanks, Geology of Point Sal, Bull. Dept. Geology, University of California, Vol. 2, pp. 1-92. H. W. Fairbanks, San Luis Folio, U. S. Geological Survey.

R. P. McLaughlin and C. A. Waring, Petroleum industry of California, Bull. 69, California State Mining Bureau. H. W. Fairbanks, Geology of Northern Ventura, etc., Report XII, State Mineralogist, pp. 493-526. F. M. Anderson, A stratigraphic study in the Mount Diablo Range of California, Proc. California Academy of Sciences, Third Ser., Geology, Vol. 2, No. 2, pp. 155-248. A. C. Lawson, The California earthquake of April 18, 1906, Report of the State Earthquake Commission, Vol. 1, part 1, 1908, pp. 1-52. R. W. Pack and W. H. English, Waltham, Priest, Bitterwater and Peachtree Valleys, California, Bull. 581-D, U. S. Geological Survey. A. C. Lawson, Sketch of the geology of the San Francisco Peninsula, 15th Annual Report, U. S. Geological Survey, pp. 403-476. A. C. Lawson, San Francisco Folio, U. S. Geological Survey. Roderic Crandall, The geology of the San Francisco Peninsula, Proc. American Phil. Society, Vol. 46, 1907, pp. 1-58. Homer Hamlin, Water resources of the Salinas Valley, California, Water Supply and Irrigation Paper No. 89, U. S. Geological Survey. G. F. Becker, Geology of the quicksilver deposits of the Pacific Slope, Mon. 13, U. S. Geological Survey. A. C. Lawson and Charles Palache, The Berkeley Hills, a detail of Coast Range geology, Bull. Dept. Geol., University of California, Vol. 2, No. 12, pp. 349-450. W. F. Jones, The geology of the Sargent oil field, Bull. Dept. Geol., University of California, Vol. 6, No. 3, pp. 55-78. A. C. Lawson, The geology of Carmelo Bay, Bull. Dept., Geol., University of California, Vol. 1, pp. 1-59. J. C. Branner, J. F. Newsom, and R. Arnold, The Santa Cruz folio, U. S. Geological Survey. Unpublished work of the summer field-geology classes of the University of California, Leland Stanford Junior University, and personal communications from W. H. Ochsner, H. Hannibal, R. B. Moran, H. R. Johnson, F. M. Anderson, C. H. Beal, E. C. Templeton, J. R. Pemberton, C. H. Davis, and C. F. Tolman, Jr.

The Northern Coast Ranges, San Francisco to Cape Mendocino.

A. C. Lawson, The geomorphogeny of the coast of northern California, Bull. Dept. Geol., University of California, Vol. 1, No. 8, pp. 241-272. V. C. Osmont, A geological section of the Coast Ranges north of San Francisco, Bull. Dept., Geol., University of California, Vol. 4, No. 3, pp. 39-87. A. C. Lawson, San Francisco folio, U. S. Geological Survey. H. W. Fairbanks, Notes on the geology of Tehama, Lake, Colusa and Napa counties, Report XI, State Mineralogist, pp. 54-75. H. W. Fairbanks, The pre-Cretaceous age of the metamorphic rocks of the California Coast Ranges, American Geologist, Vol. 9, pp. 153-166. H. W. Fairbanks, Notes on a farther study of the pre-Cretaceous rocks of the California Coast Ranges, American Geologist, Vol. 11, pp. 69-84. H. W. Fairbanks, Review of our knowledge of the geology of the California Coast Ranges, Bull. Geol., Society of America, Vol. 6, pp. 71-102.

F. M. Anderson, The geology of Point Reyes Peninsula, Bull. Dept. Geology, University of California, Vol. 2, No. 5, pp. 119-133. F. L. Ransome, The geology of Angel Island, Bull. Dept. of Geology, University of California, Vol. 1, No. 7, pp. 193-240. C. A. White, Correlation Papers; Cretaceous, Bull. 82, U. S. Geological Survey. J. S. Diller, The topographic development of the Klamath Mountains, Bull. 196, U. S. Geological Survey. T. W. Stanton, Contributions to the Cretaceous paleontology of the Pacific Coast, The fauna of the Knoxville beds, Bull. 133, U. S. Geological Survey. F. M. Anderson, Cretaceous deposits of the Pacific Coast, Proc. California Academy of Sciences, 3d Ser., Geology, Vol. 2, No. 1, pp. 1-154. G. F. Becker, Geology of the quicksilver deposits of the Pacific Slope, Mon. 13, U. S. Geological Survey. R. S. Holway, An extension of the known area of Pleistocene glaciation of the Coast Ranges of California, Bull. American Geographical Society, Vol. 43, pp. 161-170. R. S. Holway, Physiographically unfinished entrances to San Francisco Bay, University of California Pub. in Geography, Vol. 1, No. 3, pp. 81-126. In addition to these papers, unpublished work of W. B. Barber on Sonoma, of H. Hannibal on Lake and Colusa, and of W. G. Cooper and H. Hannibal on Mendocino County.

KLAMATH MOUNTAINS.

J. S. Diller, The topographic development of the Klamath Mountains, Bull. 196, U. S. Geological Survey. J. S. Diller, The Klamath Mountain section, American Journal of Science, Vol. 165, pp. 342-363. J. S. Diller, The Bragdon formation, American Journal of Science, Vol. 169, pp. 379-387. J. S. Diller, Redding folio, U. S. Geological Survey. J. S. Diller, Auriferous Gravels of the Weaverville quadrangle, Bull. 540, U. S. Geological Survey, pp. 11-21. J. S. Diller, Mineral resources of southwestern Oregon, Bull. 546, U. S. Geological Survey. O. H. Hershey, Metamorphic formations of northwestern California, American Geologist, Vol. 27, pp. 225-245. O. H. Hershey, Structure of the southern portion of the Klamath Mountains in California, American Geologist, Vol. 31, pp. 231-245. O. H. Hershey, Some evidence of two glacial stages in the Klamath Mountains, American Geologist, Vol. 31, pp. 139-156. O. H. Hershey, The Bragdon formation in northwestern California, American Geologist, Vol. 33, pp. 347-260. O. H. Hershey, The Belt and Pelona series, American Journal of Science, Vol. 184, pp. 263-273. O. H. Hershey, Del Norte County geology, Mining and Scientific Press (1911), Vol. 102, p. 468. H. W. Fairbanks, Geology and mineralogy of Shasta County, Report XI, State Mineralogist, pp. 24-53. F. M. Anderson, The physiographic features of the Klamath Mountains, Journal of Geology, Vol. 10, pp. 144-159. H. G. Ferguson, Gold lodes of the Weaverville quadrangle, California,

Bull. 540, U. S. Geological Survey, pp. 27-79. D. F. MacDonald, Gold lodes of the Carrville district, Trinity County, California, Bull. 530, U. S. Geological Survey, pp. 9-41. F. M. Anderson, H. W. Turner and other geologists, The Copper resources of California, Bull. 23, California State Mining Bureau. O. H. Hershey, unpublished geological map of Siskiyou County. H. Hannibal and W. G. Cooper, unpublished personal communications on Humboldt, Trinity, Del Norte, and Siskiyou counties. Unpublished work of the writer on the same region.

CASCADE MOUNTAINS AND MODOC LAVA FIELD.

J. S. Diller, Geology of the Lassen Peak district, 8th Annual Report, U. S. Geological Survey, Part 1, pp. 395-432. J. S. Diller, Lassen Peak folio, U. S. Geological Survey. J. S. Diller, The geology of the Taylorsville region, Bull. 353, U. S. Geological Survey. J. S. Diller, The eruptions of Lassen Peak, Mazama, Vol. 4, pp. 54-59. R. S. Holway, Preliminary report on the recent volcanic activity of Lassen Peak, University of California, Pub. in Geography, Vol. 1, No. 7, pp. 307-330. I. C. Russell, Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada, Mon. 11, U. S. Geological Survey.

THE GREAT VALLEY.

Sacramento Valley. J. S. Diller, Redding folio, U. S. Geological Survey. J. S. Diller, Tertiary revolution in the topography of the Pacific Coast, 14th Annual Report, U. S. Geological Survey, Part 2, pp. 403-433. Waldemar Lindgren, Marysville folio, U. S. Geological Survey. Waldemar Lindgren, The Auriferous Gravels of the Sierra Nevada, P. P. 73, U. S. Geological Survey. H. W. Turner, The rocks of the Sierra Nevada, 14th Annual Report, U. S. Geological Survey, Part 2, pp. 441-495. R. E. Dickerson, Fauna of the Eocene at Marysville Buttes, California, Bull. Dept. Geol., University of California, Vol. 7, No. 12, pp. 257-298. R. E. Dickerson, Fauna of the Martinez Eocene of California, Bull. Dept. Geol., University of California, Vol. 8, No. 6, pp. 61-180.

San Joaquin Valley. F. L. Ransome, The Great Valley of California, a criticism of the theory of isostasy, Bull. Dept. Geol., University of California, Vol. 1, No. 14, pp. 371-428. F. M. Anderson, A stratigraphic study in the Mount Diablo Range, Proceedings California Academy of Sciences, 3d Ser., Geology, Vol. 2, No. 2, pp. 155-248. F. M. Anderson, The Neocene deposits of Kern River, California, Proceedings, California Academy of Sciences, 4th Ser., Vol. 3, pp. 73-146. F. M. Anderson, Neocene record in the Templor basin, California, and Neocene deposits of the San Juan District, San Luis Obispo County, Proceedings California Academy of Sciences, 4th Ser., Vol. 4, pp. 15-

112. W. L. Watts, Oil and gas yielding formations of California, Bull. 19, California State Mining Bureau. R. Anderson, Preliminary report on the geology and oil prospects of the Cantua-Panoche region, California, Bull. 431, U. S. Geological Survey, pp. 58-87. R. Anderson, Preliminary report on the geology and possible oil resources of the south end of the San Joaquin Valley, California, Bull. 47, U. S. Geological Survey, pp. 106-136. R. Arnold and R. Anderson, The geology and oil resources of the Coalinga district, California, Bull. 398, U. S. Geological Survey. R. Arnold and Harry R. Johnson, Preliminary report on the McKittrick-Sunset oil region, Kern and San Luis Obispo counties, California, Bull. 406, U. S. Geological Survey. R. P. McLaughlin and C. A. Waring, Petroleum industry of California, Bull. 69, California State Mining Bureau.

FORMATIONS SHOWN ON THE MAP. PRE-CAMBRIAN METAMORPHICS.

Color, pink.

Symbol, Am.

This series includes the supposed Archæan of Inyo, San Bernardino and Riverside counties, where some of the gneisses and schists are known to underlie the lower Cambrian *Olenellus* beds. These rocks may be in part altered sediments, but appear to be chiefly granitic rocks made schistose or banded by pressure. It includes also the Pelona schists of San Bernardino County, of Hershey¹, and the Abrams and Salmon schists of Trinity and Siskiyou counties, named by the same writer, in the paper cited above; also the South Fork Mountain schists of Trinity County, named and described by J. S. Diller² but assigned by him merely to a pre-Devonian age. These pre-Devonian metamorphics of the Klamath Mountains consist partly of altered sediments, and partly of altered igneous rocks. They may be Algonkian in age, though hardly so old as the true Archæan.

This heading should also include the older schists and gneisses of the Sierra Nevada, but there are no data for separating them, since they have been mapped with the granitic rocks of the Sierra batholith. The same thing is true of similar rocks in the Sierra Madre of southern California, especially in the San Bernardino and San Jacinto batholiths.

There are also some granites included under this heading, in southeastern California, where data for separation are lacking.

SANTA LUCIA FORMATION.

Color, dark gray.

Symbol, Sl.

Schists, gneisses and crystalline limestone of the Santa Lucia Range in Monterey and San Luis Obispo counties, and Fremont's Peak of the Gavilan Range in San Benito County, have been named by Bailey

¹American Journal of Science, Vol. 184, pp. 263-273.

²American Journal of Science, Vol. 165, pp. 342-368.

Willis³ the Santa Lucia series. These rocks have never been fully described, but a partial description is given by H. W. Fairbanks⁴ without naming the series.

No definite fossils are known in the series, but round crinoid stems are said to have been found in the Gavilan limestones of Fremont's Peak. They are certainly pre-granitic, and the granite of the Santa Lucia Range is older than the Franciscan. They may be altered Paleozoics, but Hershey thinks they are pre-Cambrian. The rocks are thoroughly metamorphosed, and look as old as the pre-Cambrian rocks of southern California.

Their thickness and structural relations are unknown, but the Franciscan rocks lie unconformably upon them in the few cases where contacts have been observed. They are sometimes alluded to as altered Paleozoics, but no Paleozoic fossils have been found in the coastal region in either northern or southern California.

PALEOZOIC METAMORPHICS UNDIFFERENTIATED.

Color, pearl gray.

Symbol, Pm.

This heading includes slates, crystalline limestones, schists and altered igneous rocks, in Trinity, Humboldt, Del Norte, and Siskiyou counties. Especially notable are the great masses of serpentines in this region. This division includes all the rocks between the pre-Devonian metamorphics of Trinity and Siskiyou counties and the known Paleozoics of that region. It may also include Devonian and Carboniferous beds, but no fossils are known in the series to fix the age.

It is not a geologic formation, but a convenient catch-all for the undifferentiated metamorphic rocks of the Klamath Mountains, and may even include pre-Cambrian rocks.

The designation includes also crystalline limestones and slates of southeastern California in which no fossils are known, in that region most likely Cambrian or Ordovician. Thickness and stratigraphic relations unknown.

CAMBRIAN.

Color, lavender.

Symbol, C.

Limestones, slates and quartzites of Inyo and San Bernardino counties, Lower Cambrian *Olenellus* beds, and possibly some Middle Cambrian. Best known in the Inyo Range east of Owens River, where the series has a thickness of more than 10,000 feet.

Archacocyathus and *Olenellus* are abundant in the limestones, the corals forming reef-banks. This formation has been described by A. Knopf⁵ in the Inyo Mountains. It is the same that occurs in the

³Science, Vol. II (1900), p. 221.

⁴Geology of Northern Ventura, etc., Report XII, California State Mining Bureau, pp. 493-526.

⁵Bull. 540, U. S. Geological Survey, pp. 81-120.

Silver Peak region of Nevada, a short distance across the line from California, long known as the classic locality for lower Cambrian fossils.

S. H. Ball⁶ distinguishes in the Death Valley region of eastern Inyo County, the Prospect Mountain limestone (The *Olenellus* beds), and the Prospect Mountain quartzite. These are mappable units on large scale maps, but can not be differentiated on the twelve-mile scale.

ORDOVICIAN-SILURIAN.

Color, cobalt blue.

Symbol, S

Ordovician and Silurian quartzites of Inyo County, described by J. E. Spurr⁷ from the White Mountain Range and other desert mountains. S. H. Ball⁸ distinguishes in the Death Valley region of Inyo County, the Pogonip limestone with a thickness of 4000 feet, and the Eureka quartzite of the Amargosa Range, 1500' thick, both Ordovician. Ball lists *Orthoceras olarus* from the Pogonip, and A. Knopf⁹ lists from the Inyo Range: *Diplograptus* and *Hormotoma*, from the 4400' thick limestones of Mazourka Cañon. Ball also cites from the Amargosa Range the Lone Mountain limestone 1800' thick, supposed to be Silurian. This heading includes also the Montgomery limestone of the Grizzly formation of Indian Valley, Plumas County, described by J. S. Diller¹⁰ as containing Niagara fossils.

DEVONIAN.

Color, turquoise blue with inclined ruling.

Symbol, D.

Limestones and associated igneous rocks of Kennett and Lower Soda Springs in the Sacramento Cañon, with Middle Devonian fossils, described by J. S. Diller¹¹, also patches of limestone on the northeast side of South Fork Mountain, Trinity County, and near Gazelle, Siskiyou County. The formation is best known on the ridge between Backbone and Squaw Creeks, about 4 miles NE. of Kennett, Shasta County, where the limestone contains reefs of *Favosites canadensis*.

This heading includes also the Taylorsville formation of Indian Valley, Plumas County, described by J. S. Diller¹², assigned to this age because of its position between the Montgomery limestone and the Carboniferous beds.

Knopf¹³ described Devonian limestones from the Inyo Range, in the foothills east of Citrus Station, in Owens Valley, where they have a thickness of 1400' and contain *Spirifer maia*, *S. argentarius*, *Atrypa missouriensis*, and *Chonetes deflectus*.

⁶Bull. 308, U. S. Geological Survey.

⁷Bull. 208, U. S. Geological Survey, p. 188.

⁸Bull. 308, U. S. Geological Survey.

⁹Bull. 540, U. S. Geol. Survey, p. 86.

¹⁰Bull. 353, U. S. G. S.

¹¹Redding, Folio, U. S. G. S. and Amer. Jour. Sci., Vol. 165, pp. 342-363.

¹²Bull. 353, U. S. G. S.

¹³Bull. 540, U. S. G. S., p. 81-120.

CARBONIFEROUS.

Color, turquoise blue.

Symbol, C.

The greatest area of Carboniferous in the State is the Calaveras formation of the Gold Belt, fully described in the Gold Belt folios of the United States Geological Survey. This formation includes limestones, quartzites, some schists and igneous rocks. It is not a true geologic formation, but may include also the basement rocks on which the Carboniferous was laid down. A part of it is certainly Carboniferous, for *Fusulina cylindrica*, *Clisiophyllum gabbi*, and other characteristic fossils have been found in the limestones.

The thickness is unknown, but is certainly many thousand feet. This formation extends from Plumas to Mariposa counties, and a small patch occurs at Mineral King in Tulare County.

The Caribou limestone of the Taylorsville region of Plumas County, with *Fusulina cylindrica*, and the Robinson tuffs of the same region, with *Fusulina robusta*, described by J. S. Diller¹⁴ are also mapped under this heading.

The best section of Carboniferous on the West Coast is in the region of McCloud and Pit rivers, in Shasta County, described by J. S. Diller in the Redding folio, U. S. G. S. This section includes the Bragdon, Baird, McCloud, Nosoni and Wildwood formations, all good mappable units, but not distinguished on the 12-mile scale, for the sake of uniformity with the Gold Belt.

The Bragdon formation of Trinity and Shasta counties lies unconformably upon the Devonian, and is conformable below the Baird. It consists of conglomerates, slates, and included igneous rocks, and has a thickness of about 6000'.

O. H. Hershey¹⁵ described the Bragdon as Mesozoic, equivalent to the Mariposa formation, but J. S. Diller, in the Redding folio, proves it to be Mississippian, Lower Carboniferous.

The Baird formation, known only along the McCloud River in Shasta County, lies conformably between the underlying Bragdon and the overlying McCloud. It consists of siliceous shales and tuffs, and has a thickness of about 600'. J. P. Smith¹⁶ described the Baird as Lower Carboniferous, because of the occurrence of *Productus giganteus* and *Proetus ellipticus*, but Charles Schuchert¹⁷ thinks it is probably lower Pennsylvanian. The evidence is uncertain, for the fauna is Asiatic in affinities, wholly unlike the standard Mississippian and Pennsylvanian of the Mississippi Valley.

The McCloud limestone of Shasta County has a thickness of 2000' and contains an abundant fauna characteristic of the Coal Measures,

¹⁴Bull. 353, U. S. G. S.

¹⁵Amer. Geol., Vol. 27, p. 238.

¹⁶Jour. Geol., 1894, Vol. 2, pp. 598-612.

¹⁷Bull. Geol. Soc. Amer., Vol. 20, 1910, pp. 571-573.

especially *Fusulina cylindrica*, *F. robusta*, *Clisiophyllum gabbi*, *Lithostrotion californiense*, etc. It is the same as the Caribou limestone of Plumas County, and the *Fusulina* limestone of the Gold Belt. Large areas of this formation are known also in Inyo County, and are reported from the Mojave Desert.

The Nosoni formation of Shasta County overlies the McCloud conformably, and consists chiefly of altered tuffs (amphibolites), with some thin beds of limestones and shales; it has a thickness of about 1000' and contains numerous fossils, especially *Fusulina elongata*, several species of *Productus* allied to Permian types, of Asiatic affinities. The formation is probably transitional to Permian. Its horizon is the same as that of the Robinson tuffs of Plumas County. Similar amphibolite schists are common in the Mother Lode region, but are not known to contain fossils.

The Nosoni formation lies unconformably below the Triassic of Pit River, separated from it by masses of igneous rocks.

TRIASSIC.

Color, emerald.

Symbol, Tr.

The Triassic of California contains five different formations, Meekoceras beds of Inyo County, Parapopanoceras beds of Inyo County, Pit shales, Hosselkus limestone, and Brock shales of Shasta County. These are easily separable locally by paleontology and lithology, but the units are too small to segregate on the scale of our map. It also includes the doubtful Sailor Cañon formation of Placer County.

The Meekoceras beds are known in California only in the Inyo Range, east of Owens Lake, where they overlie the Carboniferous with apparent conformity. They have a thickness of more than a thousand feet, of shales with some limestone beds, much folded and sheared. Fossils are abundant, though badly preserved. The fauna has been described by Hyatt and Smith¹⁸ and contains *Meekoceras gracilitatis* *M. mushbachanum*, *Ussuria compressa*, *Pseudosageceras intermontanum*, and many other species characteristic of the Lower Triassic.

The Parapopanoceras beds of Inyo County lie conformably above the Meekoceras beds, and consist of shaly black limestone. The fossiliferous bed is probably not more than 50' thick, but the total thickness is probably several hundred feet. The fauna contains *Hungarites yatesi*, *Parapopanoceras haugi*, *Xenodiscus bittneri*, and *Acrochordiceras inyoense*, characteristic of the lower part of the Middle Triassic, described by J. P. Smith¹⁹.

The Pit formation, known only on Pit River and Squaw Creek, Shasta County, consists of siliceous shales and tuffs, with a thickness

¹⁸P. P. 40, U. S. G. S., Triassic Cephalopod Genera of America.

¹⁹Prof. Paper No. 83, U. S. G. S.

of about 2000'. The shales are probably of radiolarian origin, and are flinty. They contain, near Copper City, a few definite fossils: *Ptychites* sp., *Ceratites* conf. *humboldtensis*, *Tropigastrites*, and *Pentacrinus*, of Middle Triassic age, the same as those of the *Daonella* beds of the West Humboldt Range in Nevada. This formation lies conformably beneath the Hosselkus limestone.

The Hosselkus limestone of Shasta and Plumas counties is of Upper Triassic age, and has a thickness of about 400'. The beds on Brock Mountain, between Squaw Creek and Pit River, Shasta County, are full of fossils, *Tropites subbullatus*, *Sagenites herbichi*, *Paratropites sellai*, *Discotropites sandlingensis*, *Proclydonautilus triadicus*, *Halobia superba*; and reef-building corals, *Isastræa*, *Thamnastræa*, *Phyllocænia*, etc.

The Brock shales with a thickness of about 1000' overlie the Hosselkus limestone conformably, in Shasta and Plumas counties. They are dark aluminous shales with thin bands of tuffs, containing *Pseudomonotis subcircularis*, *Holorites americanus*, *Arcestes*, and *Rhabdoceras*, characteristic of the Upper Triassic, Noric horizon. The Upper Triassic faunas of California have been described by Hyatt and Smith²⁰, and the rich reptilian fauna by J. C. Merriam, in the Bulletins of the Department of Geology, University of California.

The Sailor Cañon formation of the Colfax folio, U. S. G. S., Placer County, has been described by W. Lindgren as Upper Triassic, and is included under the general heading of Triassic on the map accompanying this Bulletin. It is supposed to be the equivalent of the Brock shales.

The Cedar formation of J. S. Diller, Lassen Peak folio, U. S. G. S., is the equivalent of the Hosselkus and Brock formations.

Some small patches west of Lake Tahoe are assigned, on the basis of lithology, to the Triassic, but no fossils are known in them.

JURASSIC.

Color, gray blue.

Symbol, J.

The Jurassic of California has been better studied than any other of the older formations, because of its association with the gold-bearing veins. It includes a large number of formations which are mapped in detail on the large scale maps, but not separable on the 12-mile scale: the Hardgrave sandstone of Shasta and Plumas counties, the Modin and Potem formations of Shasta County, the Mormon, Hinchman, Thompson and Bicknell formations of Genessee Valley, Plumas County, the Mariposa, Colfax, Milton and Monte d'Oro formations of the Gold Belt folios, U. S. Geological Survey.

The Modin and Potem formations are known only on Pit River,

²⁰Prof. Paper No. 40, U. S. G. S.

Shasta County; they consist of dark shales and tuffs with thin beds of limestone; thickness about 4000'. Characteristic fossils are: *Pecten acutiplicatus*, *Pholadomya nevadana*, *Pinna expansa*. They are of Lower Jurassic age, Lias, though the upper beds may reach into the Middle Jurassic.

The Hardgrave sandstone of Plumas County consists of 500' of dark gray and reddish shales, sandstones and tuffs, and contain *Pecten acutiplicatus*, *Pholadomya nevadana*, and *Pinna expansa*, of Lower Jurassic age. The same formation occurs in the Blue Mountains of Oregon, and the West Humboldt Range of Nevada.

The Mormon, Bicknell, Hinchman, and Thompson formations of Genessee Valley, Plumas County, described by J. S. Diller²¹ are of small thickness and areal extent, important stratigraphically only because they contain the only known Middle Jurassic fauna in California. They are important geographically, because they show the last appearance of Mediterranean faunas on the West Coast before the Eocene invasion.

The Mariposa formation, known only along the Gold Belt, from Plumas to Mariposa County, includes the dark Mariposa slates, the tuffaceous beds of Colfax, and great stretches of amphibolite schists that were originally tuffs, also igneous rocks of minor extent. The Mariposa slates contain characteristic Upper Jurassic fossils at a number of places, especially the Texas ranch, six miles out from Copperopolis on the road to Sonora, Calaveras County, where the writer collected *Aucella erringtoni*, *Cardioceras alternans*, *Perisphinctes* sp., and other fossils.

The tuff beds of Colfax contain *Perisphinctes colfaxi*, and the same beds near Nashville, Amador County, contain *Simbirskites* sp.

The total thickness of the Mariposa is very great, about 10,000', including the equivalents of the Kimmeridge and the Portland formations of Europe. This apparently great thickness may be caused by folding and faulting, or may be due to the included tuff beds.

The Milton formation of the Gold Belt folios. U. S. G. S., is a synonym for the Mariposa. The Monte d'Oro formation of Butte County, in the foothills of the Sierra Nevada, is a phase of the Mariposa, containing the same auriferous quartz veins, and made up of similar tuffaceous slates. It is interesting chiefly because it contains a fine Jurassic flora, described by W. M. Fontaine²², who thinks this flora may be lower Oölite, Middle Jurassic. It is older than the Jurassic flora of southern Oregon, although many types are common to the two floras.

²¹Bull. 353, U. S. G. S.

²²20th An. Rept., part 2, U. S. G. S., pp. 342-363.

FRANCISCAN FORMATION.

Color, gray blue.

Symbol, Jf.

The Franciscan formation is well developed throughout the coastal region of California, from the Siskiyou Mountains of Del Norte, in the northern and middle Coast Ranges, the western part of the Sierra Madre Range, Santa Barbara County, and doubtfully in Orange and San Diego counties. It is also widely distributed in western Oregon, and is thought to occur also in the Olympic Range of Washington.

It is made up of cherts, altered sandstones, slates, and glaucophane-bearing schists. The beds are greatly contorted and altered, much intruded by serpentines and other igneous rocks, which are mapped with the Franciscan.

The thickness is unknown, but must be at least 15,000'. Fossils are known in the Franciscan in a few places, especially at Slate's Hot Springs, on the coast of Monterey County, where C. H. Davis²³ has described a Jurassic fauna and assigned the beds to an age not earlier than Middle Jurassic, nor later than the Mariposa.

The Franciscan rocks were first described by H. W. Fairbanks²⁴, who differentiated them from the Cretaceous, and upset the previously accepted theory of Whitney and Becker that these rocks were altered Cretaceous.

The formation was named by A. C. Lawson²⁵, who assigned them to the Cretaceous, as Whitney and Becker had done. This view is long since abandoned. The rocks are certainly pre-Cretaceous, though not necessarily, nor even probably, all Jurassic. Similar metamorphics in the Grecian Archipelago once passed for altered Cretaceous, and have since turned out to be Paleozoic.

There are in the Franciscan great masses of serpentine and numerous smaller areas of dyke rocks, mapped with the formation, though they are intrusive in it, and therefore younger.

The Franciscan is certainly pre-Knoxville; in the Santa Lucia Mountains it contains Jurassic fossils, and overlies unconformably the Santa Lucia series.

At the end of the Franciscan and the Mariposa epochs came the great Cordilleran Mesozoic revolution, in which the mountain ranges of Western America were uplifted, great masses of granite were thrust into the superjacent formations, and quartz veins were mineralized. This was the most important event in the geologic history of California, and prepared the way for the future wealth of the State.

²³New species from the Santa Lucia Mountains, California, with a discussion of the Jurassic age of the slates at Slate's Springs. *Jour. Geol.*, Vol. 21, 1913, pp. 453-458.

²⁴Pre-Cretaceous age of the metamorphic rocks of the California Coast Ranges. *Amer. Geol.*, Vol. 9, pp. 153-166; and Notes on a farther study of the pre-Cretaceous rocks of the California Coast Ranges. *Amer. Geol.*, Vol. 11, pp. 69-84.

²⁵Sketch of the geology of the San Francisco Peninsula. 15th An. Rept., U. S. G. S., pp. 401-476.

CRETACEOUS.

There are two units under the Cretaceous, the lower, containing the Knoxville, and the Horsetown formations; and the Upper, containing the Chico. The broad band on the eastern side of the Coast Ranges from Shasta County southward consists chiefly of Knoxville; that on the ocean side consists chiefly of Chico.

UNDIFFERENTIATED.

Color, Nile green.

Symbol, K.

Marine sandstones and shales without distinctive fossils.

LOWER CRETACEOUS.

Color, olive green.

Symbol, Kk.

The Knoxville formation, consisting of shales, sandstones, and conglomerates, lies unconformably upon the Franciscan rocks, but is greatly mixed with them by folding and faulting. The rocks are darkened, but not greatly altered nor mineralized.

The thickness of the formation is about 20,000', and it extends from southwestern Oregon to San Luis Obispo, never reaching eastward of the Coast Ranges. Some of the areas mapped as Lower Cretaceous probably contain some Franciscan, for even on large-scale maps a separation is difficult.

The formation may be divided paleontologically into two divisions: lower Knoxville, with *Aucella piochi* and *Phylloceras knoxvillense*; and upper Knoxville, with *Aucella crassa* and *A. crassicollis*. These are not mapable divisions.

The lower Knoxville, in southern Oregon, and northern California, contains a flora described by W. M. Fontaine²⁶ as Upper Jurassic. The upper Knoxville and Horsetown formations contain a flora described by Fontaine²⁷ as the Shasta Flora, and assigned by him to the Neocomian division of the Lower Cretaceous. J. S. Diller²⁸ doubts the Jurassic age of the Oregon flora, and assigns it to the Lower Cretaceous. The evidence brought up by F. H. Knowlton²⁹ seems to show that the fossil flora of the lower Knoxville is uppermost Jurassic, though post-Mariposa. The break between Mariposa and Knoxville does not coincide with the dividing line between Jurassic and Cretaceous. The upper Knoxville is certainly Neocomian, Lower Cretaceous.

The Knoxville fauna has been fully described by T. W. Stanton in Bull. 133, U. S. G. S.

Horsetown formation. This is known certainly only in northern California, where it has been described by J. S. Diller, in the Redding folio, U. S. G. S. It consists of about 6000' of calcareous shales and

²⁶Mon. 48, U. S. G. S., pp. 48-145.

²⁷Mon. 48, U. S. G. S., pp. 211-277.

²⁸Bull. Geol. Soc. Amer., Vol. 19 (1908), pp. 367-402.

²⁹Amer. Jour. Sci., Vol. 30, 4th ser. (1910), pp. 33-34; 63-64.

sandstones, lying unconformably upon the Knoxville, but conformably below the Chico. It contains, in the region of Cottonwood and Hulen creeks, southwest of Redding, a rich fauna, especially: *Lytoceras batesi*, *Phylloceras onocense*, *Schloenbachia*, *Desmoceras hoffmanni*, *Hoplites remondi*. The age is probably upper Gault and possibly lowest Cenomanian. This formation has been listed from the Mt. Diablo region, but is doubtful there.

UPPER CRETACEOUS.

Color, light green.

Symbol, Ke.

The Upper Cretaceous of California includes only the Chico formation, which is distributed along the West Coast from Puget Sound to Lower California, chiefly in the Coast Ranges, and on the west side of the Great Valley, but overlaps on the western flank of the Sierra Nevada, near Oroville, in Butte County. It may be divided paleontologically into: lower Chico, with *Schloenbachia oregonensis*; and upper Chico, with *Placenticeras*. The lower Chico is probably upper Cenomanian and Turonian in age, equivalent to the Colorado formation, while the upper Chico is probably Senonian, equivalent to the Montana formation. They are not separable as mapping units, since they are perfectly conformable and have the same lithology.

The lower Chico is best known in southern Oregon, Shasta County, California, and the Santa Ana Mountains in Orange County. The upper Chico is best known in the Coast Ranges from San Francisco southward, especially in the coastal part of the Sierra Madre Range in southern California.

The stratigraphy and paleontology of the Chico have been described by F. M. Anderson.³⁰

The Chico beds as a whole consist chiefly of yellowish sandstones with some limy shales. Their thickness is probably at least 4000' where the whole formation is present.

TERTIARY.

EOCENE.

Color, orange.

Symbol, Te.

The Eocene includes the Martinez and Tejon formations, and also the Ione, which is a synonym of Tejon.

Martinez. This formation consists of about 4000' of sandstones in the region of San Francisco Bay, and in the Santa Monica Mountains in southern California. It lies unconformably between the Chico and the Tejon. The most characteristic fossils are: *Venericardia planicosta*, *Pholadomya nasuta*, *Cucullaea matthewsoni*, *Turritella martinezensis*, and many others.

³⁰Cretaceous deposits of the Pacific Coast, Proc. Calif. Acad. Sci., 3d Series, Geol., Vol. 2, No. 1, pp. 1-152.

The stratigraphy and paleontology of the Martinez have been fully described by R. E. Dickerson.³¹

Tejon. This formation has a thickness of about 10,000', chiefly of yellowish sandstones. It occurs from Cape Flattery to San Diego, chiefly in the Coast Ranges, western side of the Great Valley, and a narrow fringe along the western base of the Sierra Nevada. It lies unconformably between the Martinez and the Oligocene. Its very rich fauna has been described in many papers by T. A. Conrad, W. M. Gabb, W. H. Dall, R. Arnold, R. E. Dickerson³² and C. A. Waring. Some of the most characteristic fossils are: *Venericardia planicosta*, *Cardium cooperi*, *Crassatella uvasana*, *Turritella uvasana*.

The **Ione** formation, of the western flank of the Sierra Nevada, was originally described as upper Miocene, but has been shown by R. E. Dickerson, H. Hannibal and others to be upper Eocene. It contains many species of the marine fauna and characteristic flora of the Tejon formation but probably represents, in part at least, a later period of time and sedimentation.

The Topatopa formation of southern California, described by Eldridge and Arnold³³, is a synonym of Tejon.

The fossil flora of the Tejon is almost as characteristic as the invertebrate fauna, being also distinctly subtropical. It is best known in the Tesla region of the Mount Diablo Range, and in the foothills of the Sierra Nevada. Among the characteristic plants are: *Sabalites californica*, *Geonomites schimperii*, *Magnolia californica*, *Laurus* sp., and *Juglans californica*.

AURIFEROUS GRAVELS.

Color, orange.

This formation consists of ancient river gravels on the western flank of the Sierra Nevada, and in the Klamath Mountains. The older gravels are contemporaneous with the Ione, and hence are Eocene, as shown by R. E. Dickerson. The later gravels of the volcanic and post-volcanic epochs are thought to be Miocene. W. Lindgren³⁴ has fully described this formation, and assigned it to the upper Miocene, but this was before the work of Dickerson was published. The flora of the older gravels is the same as that of the Tejon beds of the Tesla region, where they are interbedded with a typical Eocene marine fauna.

MIOCENE.

Color, cadmium yellow.

Symbol, Tm.

The Miocene is widely distributed in the middle Coast Ranges from San Francisco southward; along the western side and southern end of

³¹Fauna of the Martinez Eocene of California. Bull. Dept. Geol., Univ. of California, Vol. 8, No. 6 (1914), pp. 61-180.

³²Stratigraphy and fauna of the Tejon Eocene of California. Univ. of Cal. Pub. Bull., Dept. Geol., Vol. 9, No. 17, pp. 363-524, 1916.

³³Bull. 309, U. S. G. S.

³⁴The Auriferous Gravels of the Sierra Nevada, Prof. Pap. 73, U. S. G. S.

the San Joaquin Valley; and on the coastal side of the Sierra Madre as far as Orange County. Lake beds of this age are extensively developed in Trinity and Lake counties, and in the Sierra Nevada. Continental accumulations are known in Kern, Inyo and San Bernardino counties.

Under the Miocene the San Lorenzo Oligocene beds of the Santa Cruz Mountains are included, because the scale of the map is too small for their separation. For the same reason the Sespe formation of the Santa Ynez Mountains, is mapped with the Miocene, although Arnold supposed it to be Oligocene.

The Miocene proper includes the following formations, beginning with the older beds.

Lower Miocene. Vaqueros formation, described by Fairbanks, San Luis Folio, U. S. G. S., and more fully by J. C. Branner, J. F. Newsom, and R. Arnold in the Santa Cruz Folio, U. S. G. S. It consists of several thousand feet of hard yellowish gray sandstones and conglomerates, well developed in the Santa Cruz Mountains; the east side of the Santa Lucia Mountains (the type section); the Santa Ynez Mountains; and the Santa Monica Mountains. It is not known north of San Francisco, nor east of the Coast Ranges.

Characteristic fossils are *Pecten magnolia*, *Turritella inezana* = (*T. hoffmanni*) and *Scutella fairbanksi*.

Monterey. The Monterey formation was first named by Blake in the Pacific R. R. Reports, to include the diatomaceous shales of the Coast Ranges; re-named and described by A. C. Lawson³⁵ to include the sandy facies of the same series; later more fully described and discussed by G. D. Louderback³⁶, who includes also the Vaqueros formation under this series.

The Monterey shale facies is best known in the middle Coast Ranges, where it reaches a thickness of 5000', and is the chief source of the petroleum of California. The sandy facies is best known in the Contra Costa Hills; the southeast side of the Santa Lucia Mountains; the Coalinga oil fields; the Kern oil fields; and the Santa Monica Mountains.

The sandy facies of the Monterey has been called the Temblor formation by F. M. Anderson³⁷, with the fauna of the Kern oil fields, Barker's ranch, as the type. Arnold³⁸ calls these beds Vaqueros, but later usage has placed them under the Monterey.

Characteristic fossils are: *Pecten andersoni*, *P. miguelensis*, *Chione temblorensis*, *Ficus kernianus*, *Agasoma barkerianum*, and *Turritella ocoyana*.

³⁵Geology of Carmelo Bay, Bull. Dept. Geol., Univ. of Cal., Vol. 1.

³⁶The Monterey series in California, Bull. Dept. Geol., Univ. of Cal., Vol. 7, No. 10.

³⁷A stratigraphic study in the Mount Diablo Range of California, Proc. Calif. Acad. Sci., 3d Ser. Geol., Vol. 2, No. 2, pp. 155-248.

³⁸Bull. 398, U. S. G. S.

At the top of the Monterey in Alameda and Contra Costa counties lie the Briones beds, zone of *Scutella breueriana*, included by Lawson³⁹ under the Monterey.

After the Monterey epoch came the uplift and mountain-making of the Coast Ranges, hardening all the older Tertiary rocks, and inaugurating the modern topography of the State.

Upper Miocene. Santa Margarita formation of the east side of Salinas Valley, and the Coalinga oil fields, light gray granitic sandstones, and sandy shales, thickness about 1200'. These beds were first definitely named by Fairbanks in the San Luis Obispo Folio, U. S. G. S.; their fauna has been fully described by R. Arnold⁴⁰, who calls the formation middle Miocene. The Jacalitos beds have been separated from the Santa Margarita by R. Arnold⁴¹ on the basis of a slight unconformity.

The most characteristic fossils of the Santa Margarita are: *Pecten crassicardo*, *P. estrellanus*, *Ostrea titan*, *Tamiosoma gregaria*, and *Astrodapsis antiselli*. The most distinctive fossils of the Jacalitos are: *Pecten oweni*, and *Scutella gibbsi*, *Trophon ponderosus*, and the earliest of the Pliocene types.

The San Pablo formation, named by J. C. Merriam⁴² to include the Miocene beds of San Pablo Bay, is the equivalent of the Santa Margarita and possibly the Jacalitos formations, and is especially characterized by *Pecten pabloensis*, *Astrodapsis tumidus* and *A. whitneyi*. This fauna has been studied and described by B. L. Clark⁴³.

The Mohawk lake beds of Plumas County, formerly called Pleistocene, the Truckee lake beds of Nevada County, and the Esmeralda lake beds east of the Sierra Nevada, are included under the Miocene, along with the continental accumulations of Kern, San Bernardino and Inyo counties. The uppermost beds of the desert region described by C. L. Baker⁴⁴ contain a Pliocene fauna of vertebrates, but can not be separated in mapping on a small scale.

The Cache lake beds of the Clear Lake region, described by Becker⁴⁵, are included under the Miocene; also the beds of Hay Fork and Hyampom in Trinity County.

Under the Miocene are classed also the Tuscan tuffs at the head of the Sacramento Valley. These were formerly mapped as Pliocene, because they overlie the Ione formation, formerly called Miocene, now known to be Eocene.

³⁹San Francisco Folio, U. S. G. S.

⁴⁰The paleontology of the Coalinga district, Fresno and Kings counties, California, Bull. 396, U. S. G. S.

⁴¹Bull. 398, U. S. G. S.

⁴²Bull. Dept. Geol., Univ. of Calif., Vol. 2, No. 4, pp. 109-118; and Jour. Geol., Vol. 6, pp. 483-499 (quoted by H. W. Turner).

⁴³Fauna of The San Pablo Group of middle California, Bull. Dept. Geol., Univ. of California, Vol. 8, No. 22, pp. 385-572, 1915.

⁴⁴Bull. Dept. Geol., Univ. of Calif., Vol. 6, No. 15, pp. 333-383.

⁴⁵Mon. 13, U. S. G. S.

PLIOCENE.

Color, lemon yellow.

Symbol, Tp.

The Pliocene includes the San Diego formation of San Diego, the Merced formation of the San Francisco Peninsula; the Wildeat formation of Humboldt County; the Fernando formation of southern California; the Etchegoin formation of the Coalinga oil fields; the Purisima formation of the Santa Cruz folio, all at least approximately contemporaneous; also the Carrizo formation of Imperial and San Diego counties, which probably includes uppermost Miocene along with the Pliocene.

These formations have received different names because of their geographic occurrence, and the climatic influences on their faunas.

The Carrizo formation is strictly tropical, characterized by *Pinna*, *Dolium*, and tropical types of sea-urchins, *Encope tenuis*, *Clypeaster bowersi*, *C. deserti*, etc.

Arnold⁴⁶ called this formation Miocene, influenced by the tropical character of the fauna; but this is the head of the ancient Gulf of California, and would be tropical even now, if the sea had access to it.

The San Diego and lower Fernando formations of the coastal region of southern California are warm temperate in character, characterized by *Pecten ashleyi*, *P. healeyi*, *P. hemphilli*, *P. merriami*, *Ficus nodiferus*, *Scutella ashleyi*, *Astrodapsis fernandoensis*.

The Etchegoin beds of the Coalinga region are still characterized by warm temperate species; they were described by F. M. Anderson as Pliocene, but R. Arnold⁴⁷ influenced by the strong contrast with the Merced fauna, called them upper Miocene. They are now generally admitted to be lower Pliocene. Among the most characteristic fossils of the Etchegoin are: *Pecten oweni*, *P. coalingaensis*, *Scutella gibbsi*, *Mytilus coalingaensis*, *Thais kettelmanensis*, etc.

The Merced-Purisima beds of the San Francisco Peninsula and the Santa Cruz Mountains have a more northern type of fauna. *Pecten healeyi*, *P. oweni*, *Chrysodomus imperialis*, *C. tabulatus*, *Chione securis*, *Paphia staley*, *Scutella interlineata*. This same fauna occurs in the Wildeat beds of Eel River, except that *Pecten healeyi* and *P. oweni* are lacking.

Still further north, on the coasts of Oregon and Washington, the facies of the Pliocene inclines to sub-boreal.

In southern California the Fernando beds are overlain by still younger Pliocene, called the Santa Barbara formation, characterized by more modern and cooler water types than those of the Fernando.

The Merced has a thickness of 5000', the other contemporaneous formations of the Pliocene are much thinner; all are little consolidated

⁴⁶Prof. Paper No. 47, U. S. G. S (1906).

⁴⁷Bull. 398, U. S. G. S.

sandstones and shales, much softer and less disturbed than the Miocene formations. The Paso Robles estuarine beds of the Salinas Valley, the Santa Clara lake beds of the region of San Francisco Bay, and the Tulare lake beds of the Coalinga region are included under the Pliocene.

TERTIARY UNDIFFERENTIATED.

Color, chrome yellow with inclined ruling. Symbol, T.

This heading includes continental beds partly formed by rivers and partly by deposition in ponds. In most cases these undifferentiated beds are either Miocene or Pliocene.

A small area of marine deposits north of San Diego is mapped as Tertiary undifferentiated, because it is supposed to contain Eocene, Miocene and Pliocene beds, but they have not been separated on maps.

QUATERNARY.

Color, light buff. Symbol, Q.

The Quaternary includes the San Pedro marine formation of the coast of southern California; older alluvium and delta formations of the Great Valley and other valleys; lake beds in various parts of the State; desert wash of southeastern California; and glacial deposits, where differentiated.

The San Pedro formation is entirely marine, and has a thickness of about 1000'; it is characterized by a fauna almost exactly like that now living.

The brea deposits of southern California contain a Pleistocene vertebrate fauna unlike anything now living; this is true also of the Quaternary cave deposits in northern California. The river alluvium also contains many extinct forms.

IGNEOUS ROCKS.

VOLCANIC ROCKS.

Color, salmon pink. Symbol, V.

The volcanic rocks shown on the map are surface flows, chiefly andesites, but with some basalts and rhyolites, mostly of Tertiary age, but including the Quaternary lavas of Mount Shasta, Lassen Peak and the eastern side of the Sierra Nevada.

The Modoc lava sheet covers eastern Siskiyou and eastern Shasta counties, and all of Modoc and Lassen; Mount Shasta and Lassen Peak form a southward extension of the Cascade Range.

The volcanic region of Clear Lake covers extensive stretches of Lake, Sonoma and Napa counties. The Tertiary volcanic flows of the Sierra Nevada cover large areas from Plumas to Tuolumne County. The Great Basin volcanics are extensively developed from Alpine to Inyo

County, on the east side of the Sierra Nevada. There are small patches in the middle Coast Ranges, and much larger ones in the Mojave Desert of Kern and San Bernardino counties.

PLUTONIC ROCKS.

Color, cerise.

Symbol, P.

Under the plutonic rocks are grouped the batholiths of granite, granodiorite, gabbro and quartz diorite that occur in the core of most of the mountain ranges of California.

The greatest batholith in the State is that of the Sierra Nevada, extending from Plumas County to Tejon Pass in the Tehachapi Mountains. It is composed chiefly of granodiorite, but contains also typical granite, quartz diorite, and gabbro. Its age is supposed to be late Jurassic, for at Indian Gulch in Mariposa County a dyke of granite cuts across and metamorphoses the Mariposa slates. However, it is not likely that this immense batholith was formed all in one age, for rolled pebbles of granitic rocks are reported from the Carboniferous, the Triassic and the Jurassic sediments of the Sierra Nevada.

The second greatest batholith is that of the Sierra Madre, beginning with the San Gabriel Mountains of Los Angeles County and running southeast through the San Jacinto Mountains and the San Bernardino Range to Lower California. This range is like the Sierra Nevada in constitution, but has more of gneisses and schists in its make-up. Nothing is known of its age, except that in the Santa Ana Mountains of Orange County the granitic rock has altered Triassic strata.

Throughout the Mojave and Colorado deserts there are bosses of true granite, and numerous large patches of gneiss that are probably granitic. These may belong to the pre-Cambrian, even Archæan, and are mapped as plutonic only where they are known to be intrusive.

In the Klamath Mountains of Siskiyou, Shasta, Trinity and Del Norte counties there are numerous batholiths of granitic rocks, very like those of the Sierra Nevada, and supposed to belong to the same period. But since no fossiliferous sediments of later age than Upper Carboniferous are invaded by these rocks, no definite age can be assigned to them. And since the batholiths are isolated, we do not know that they all belong to one great intrusive mass.

The core of the Coast Ranges is undoubtedly a batholith, or series of batholiths. Granitic rocks crop out underneath the later sediments at a number of places, showing small bosses in San Luis Obispo County, and large masses in the Santa Lucia Mountains of Monterey County, with some small patches in Santa Cruz, San Mateo and Marin counties. The Farallone Islands are such a denuded remnant of the axis of the Coast Ranges. All through the Coast Ranges the great abundance of granitic sands shows the former surface extent of this batholith.

We know little of the age of these granitic rocks. In the Santa Lucia Mountains the Franciscan rocks are said to lie upon the eroded surface of granite, which is therefore pre-Franciscan there. Whether the other bosses are of the same age can not be said. At any rate they are all pre-Cretaceous.

The rocks of the Sierra Nevada have been fully described by H. W. Turner and W. Lindgren, in papers cited above; those of the Sierra Madre partially studied by R. Arnold, O. H. Hershey and A. M. Strong; those of the Coast Ranges by A. C. Lawson; those of the Klamath Mountains by J. S. Diller and O. H. Hershey. A petrographic study of these batholiths is one of the great needs in the geology of California.

PETROLEUM.

Color, black.

Symbol, Oil.

The proven oil areas in California total 80,702 acres, or 126 square miles. On the geologic map the larger commercially productive fields are indicated by cross-hatched areas; smaller occurrences and less extensive producing areas by solid black.

APPENDIX.

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Samples (limited to three at one time) of any mineral found in the state may be sent to the Bureau for identification, and the same will be classified free of charge. No samples will be determined if received from points outside the state. It must be understood that no assays, or quantitative determinations will be made. Samples should be in lump form if possible, and marked plainly with name of sender on outside of package, etc. No samples will be received unless delivery charges are prepaid. A letter should accompany sample, giving locality where mineral was found and the nature of the information desired.

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